ANSWERS: Comparing and contrasting properties of substances

ductile and soluble in cyclohexane (non-polar solvent) and conducts electricity	state of matter at room temperature
Magnesium atoms are held together in a 3–D lattice by metallic bonding in which valence electrons are attracted to the nuclei of neighbouring atoms. Iodine molecules are held together by weak intermolecular forces. **Ductility** The attraction of the Mg atoms for the valence electrons is not in any particular direction; therefore Mg atoms can move past one another without disrupting the metallic bonding, therefore Mg is ductile. The attractions between iodine molecules are directional. If pressure is applied the repulsion between like-charged ions will break the solid, therefore I_2 is not ductile. **Dissolving in cyclohexane** Magnesium does not dissolve in cyclohexane because cyclohexane molecules are not attracted to the magnesium atoms in the metallic lattice. Iodine is soluble, as iodine is a non-polar molecule. The iodine molecules and cyclohexane molecules form weak	Chlorine is a molecular substance composed of chlorine molecules held together by weak intermolecular forces. The weak intermolecular forces do not require much heat energy to break, so the boiling point is low (lower than room temperature); therefore chlorine is a gas at room temperature. Copper chloride is an ionic substance. It is composed of a lattice of positive copper ions and negative chloride ions held together by electrostatic attraction between these positive and negative ions. These are strong forces, therefore they require considerable energy to disrupt them and melt the copper chloride; hence copper chloride is a solid at room temperature.

electrical conductivity	electrical conductivity and solubility in water
For a substance to conduct electricity, it must have charged particles which are free to move. Graphite is a covalent network solid composed of layers of C atoms covalently bonded to three other C atoms. The remaining valence electron is delocalised (ie free to move) between layers; therefore these delocalised electrons are able to conduct electricity. Copper is a metallic substance composed of copper atoms packed together. Valence electrons are loosely held and are attracted to the nuclei of the neighbouring Cu atoms; ie the bonding is non-directional. These delocalised valence electrons are able to conduct an electrical current. For a substance to be made into wires, it needs to be stretched or drawn out without breaking. In graphite, the attractive forces holding the layers together are very weak and are broken easily, so the layers easily slide over one another, but the attraction is not strong enough to hold the layers together and allow it to be drawn into wires or although the layers can slide due to weak forces, if graphite was to be made into a wire the very strong covalent bonds within the layers would have to be broken. Copper metal can easily be drawn into wires since, as it is stretched out, the non-directional metallic bonding holds the layers together, allowing it to be stretched without breaking.	Zinc atoms are held together in a 3–D lattice by metallic bonding in which valence electrons are attracted to the nuclei of neighbouring atoms. Zinc chloride is made up of positive zinc ions and negative chloride ions held together by electrostatic attractions in a 3–D lattice. **Conductivity** Zinc chloride does not conduct electricity as a solid as these ions are not free to move around. (When dissolved in water, the ions are free to move and carry the charge so zinc chloride solution conducts electricity.) In zinc metal the delocalised electrons / valence electrons are free to move through the lattice; therefore they are able to conduct electricity. **Solubility** Zinc does not dissolve in water because water molecules are not attracted to the zinc atoms in the metallic lattice. Water molecules are polar. When zinc chloride is dissolved in water the attractions between the polar water molecules and between the ions in the salt are replaced by attractions between the water molecules and the ions. The negative charge on the oxygen ends of the water molecules are attracted to the positive Zn^{2+} ions, and the positive hydrogen ends of the water molecules are attracted to the negative Cl^{-} ions.

melting point and solubility	melting point and solubility	malleability and solubility
Bonding in **SiO_2** is covalent bonds Bonding in **Br_2** is weak intermolecular forces of attraction. SiO_2 is made up of Si and O atoms. Each atom is covalently bonding to four others in a tetrahedral arrangement forming a covalent network solid. The covalent bonds are very strong and: • (for melting point) require a large amount of energy to overcome them, meaning SiO_2 has a high melting point • (for solubility) are too strong to be broken by the attraction to the water molecules. Br_2 is a molecular substance made up of molecules. There are weak intermolecular forces holding the molecules together and: • (for melting point) require only a small amount of energy to overcome them meaning Br_2 has a low melting point (for solubility) the attraction of the water molecules is sufficient to separate the bromine molecules, meaning Br_2 is soluble in water.	$MgCl_2$ is made up of ions SiO_2 is made up of atoms. Both solids have a high melting point. $MgCl_2$ has a high melting point. It is an ionic solid. It consists of a 3–D lattice of **positive Mg^{2+} ions and Cl^- ions** and the ions are held together by strong ionic bonds. As a lot of energy is required to overcome these strong bonds to separate the ions, the solid has a high melting point. SiO_2 is a covalent network solid. The atoms in SiO_2 are held together by strong covalent bonds. A lot of energy is required to break these bonds in order for the solid to melt; therefore it has a high melting point. $MgCl_2$ is soluble in water, whereas SiO_2 is not. Water molecules are polar. When $MgCl_2$ is placed in water, the oxygen ends of the water molecules are attracted to the positive Mg^{2+} ions, and the hydrogen ends of the water molecules are attracted to the negative Cl^- ions. The water molecules then pull ions from/destroy the lattice, resulting in the solid dissolving. SiO_2 is not soluble in water, as the covalent bonds are too strong to be broken by the attraction to the water molecules.	Zinc consists of Zn atoms held together in a 3–D lattice by metallic bonding, in which valence electrons are attracted to the nuclei of neighbouring atoms. The attraction of the zinc atoms for the valence electrons is not in any particular direction, so therefore zinc atoms can move past one another, and so zinc is malleable. Zinc is not soluble in water, as the metallic bonds are too strong to be broken by the attraction to the water molecules. Zinc chloride consists of a regular array of zinc and chloride ions held together by ionic bonds in a lattice. The bonds within $ZnCl_2$ are directional so $ZnCl_2$ is not malleable. $ZnCl_2$ will dissolve in water as water is polar and the partial charges on water are attracted to the oppositely charged ion. (This attraction is sufficient to pull the ions from the lattice.)

melting point	melting and boiling points	melting point and conductivity and hardness
(S_8) molecules Intermolecular forces / dispersion forces / Van Der Waals forces / London forces. (Si and O) atoms Covalent bonds. The atoms in SiO_2 are held together by strong covalent bonds. A lot of energy is required to break these bonds in order for the substance to melt. When S_8 melts, the weak intermolecular forces between molecules must be broken. Less energy is required to break these forces.	NaCl and $MgCl_2$ both have high melting and boiling points. These are ionic substances. They consist of a 3–D lattice of positive metal ions and Cl^- ions and the ions are held together by strong ionic bonds. As a lot of energy is required to overcome these strong forces and separate the ions, the substances have high melting and boiling points. PCl_3 and SCl_2 both have low melting and boiling points. These are molecular substances. They consist of molecules and the molecules are attracted to each other by weak intermolecular or van der Waals forces. As not much energy is required to overcome these weak forces and separate the molecules, the substances have low melting and boiling points.	CO_2 Exists as molecules. Weak van der Waals forces exist between the molecules. As all valence electrons are involved in forming covalent bonds there are no free moving charges and so no electrical conduction. As the van der Waals forces between molecules are weak these are easily overcome hence little energy is required to separate the molecules [therefore has a low MP/sublimes at -78°C]. Also since the weak van der Waals forces allow the molecules to be easily separated this makes it brittle /(easy to break the solid). SiO_2 Exists as 3−D covalent network. Strong covalent bonds hold the Si and O atoms together in a 3−D arrangement. As all valence electrons are involved in forming covalent bonds there are no free moving charges and so no electrical conduction. As the covalent bonds between atoms are strong they require a lot of energy to overcome and separate atoms so the melting point is very high. Also since the strong covalent bonds hold the atoms firmly in the 3−D structure, the solid is very hard.